

Development and flight qualification of a miniature absolute scalar magnetometer

Completed Technology Project (2016 - 2019)



Project Introduction

Electric currents relay stresses between regions of the magnetosphere and are a fundamental quantity in determining the electrodynamics of the geospace system. Precise measurement of small-scale currents in the magnetosphere requires simultaneous multi-point measurements of the magnetic field to an accuracy of 1 nT or better by satellite constellations. Fluxgate magnetometers alone cannot deliver such performance because their calibration can drift so that long-term stability is not guaranteed. The proven solution is to partner the fluxgate instruments with an absolute reference magnetometer, which serves as an in-flight calibration source. We have developed a low-resource, miniaturized, absolute scalar magnetometer based on the rubidium isotope ^{87}Rb . Our sensor employs a low-power semiconductor laser and a miniature rubidium vapor cell of millimeter dimensions produced using modern micro-fabrication processes. The combination of MEMS vapor cell and a semiconductor diode laser has demonstrated reductions of power requirements and mass by one to two orders of magnitude over conventional instruments. The resulting instrument has a total mass of less than 500 g and uses 0.5 W of power, while maintaining sensitivity, 15 pT/ $\sqrt{\text{Hz}}$ at 1 Hz or about 0.1 nT rms. The prototype instrument has demonstrated that absolute magnetometers can be miniaturized to serve future heliophysics missions even under severe resource constraints. This proposal is to develop the first flight-qualified implementation of this instrument and test it via a ride-along flight on a sounding rocket. The magnetometer will consist of two sensors oriented suitably to avoid insensitivities for certain directions of the ambient field with respect to the sensor's optical axis and custom mixed-signal electronics to control the magnetometer sensor package. Successful flight operation of the proposed miniature magnetometer will not only demonstrate reliability for future heliophysics missions but also support the sounding rocket investigation by providing a precise measurement of the ambient magnetic field strength as a reference for reduction of vector magnetometer data and for determining particle gyro-frequencies to allow accurate scaling of plasma cutoffs, resonances, and other characteristic frequencies. We propose to develop a flight-ready, ultra-precise atomic scalar magnetometer and qualify the instrument for space flight via a ride-along opportunity on a sounding rocket experiment already funded for development by NASA's heliophysics program for launch in 2018. As an added benefit, the proposed effort will support the science investigation of the rocket experiment without request for additional resources. The National Research Council Decadal Strategy for Solar and Space Physics report recognizes that future advances in heliophysics research depend critically on infusion of new technology to implement upcoming heliophysics missions, such as MEDICI and GDC, in an affordable manner. The advanced fabrication techniques, such as design of custom electronics and micro-electromechanical systems (MEMS) devices proposed here, enable miniaturization of research instruments to reduce spacecraft mass and power resources, which are substantial drivers of launch cost. The proposed effort is thus highly relevant to the Heliophysics Technology and Instrument



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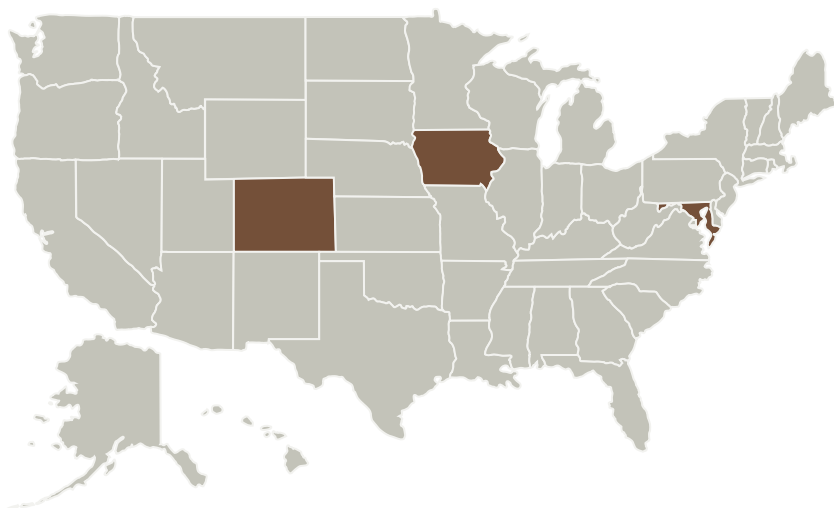
Development for Science (H-TiDeS) element of the Heliophysics Research Program. The effort is timely because of the unique ride-along opportunity, which allows risk reduction of the transforming technology in time for proposals to the above missions.

Anticipated Benefits

Support NASA's strategic objectives to understand the Sun and its interactions with Earth and the solar system, including space weather. This will be achieved by developing/demonstrating instrumentation technology necessary to address the following science goals:

- Explore the physical processes in the space environment from the Sun to the Earth and throughout the solar system;
- Advance our understanding of the connections that link the Sun, the Earth, planetary space environments, and the outer reaches of our solar system;
- Develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society and to safeguard human and robotic explorers beyond Earth.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Johns Hopkins University	Lead Organization	Academia	Baltimore, Maryland

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Johns Hopkins University

Responsible Program:

Heliophysics Technology and Instrument Development for Science

Project Management

Program Director:

Roshanak Hakimzadeh

Program Manager:

Roshanak Hakimzadeh

Principal Investigator:

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Primary U.S. Work Locations

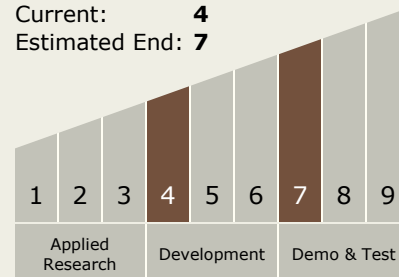
Colorado

Iowa

Maryland

Technology Maturity (TRL)

Start: **4**
Current: **4**
Estimated End: **7**



Technology Areas

Primary:

- TX08 Sensors and Instruments
 - TX08.3 In-Situ Instruments and Sensors
 - TX08.3.1 Field and Particle Detectors

Target Destination

The Sun